Public Attitudes to GM Foods: The Balancing of Risks and Gains

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ABSTRACT

In the paper we study the variables influencing attitudes to the use of two biotechnologies related to gene transfer within apples. Using Eurobarometer 73.1 survey data on biotechnology, science and technology, with 15650 respondents, we study the extent these attitudes are determined by socio-economic and other variables. We found that attitudes to the risks and gains are determined by socio-economic variables and also by the individual's knowledge, scientific background, their parent's education in science and their religion. Perceptions of naturalness and of environmental impact combine with perceived risks and gains in determining overall approval, proxied by views on whether the technologies should be encouraged, for GMTs. However there are substantial differences in attitudes to transgenesis and cisgenesis

Keywords: Genetically modified technologies; gene transfer, scientific background.

Introduction

Interest in transgenic foods has grown rapidly in recent decades. But their use has nonetheless been limited by both technical problems and a substantial scepticism among the general public. One of the public's major concerns is the artificial combination of genetic elements derived from different organisms that cannot be crossed by natural means (Holme, Wendt & Holm 2013). Partially because of this scepticsm, cisgenesis was developed as an alternative to transgenic crop development. Initially the main principle was that the genes or gene elements should be derived from the species itself (Jochemsen and Schouten, 2000). But this was later extended to include the gene pool of sexually compatible species. There is indeed evidence that the public view cisgeneis more favourably than transgenesis (McComas et al., 2014). This is part of a literature which has shown that consumers' risk perceptions of food innovations play a major role in their acceptance (Cardello, 2003).

The relative hostility to GM foods in the EU has meant that their development in Europe has been much more limited than in the USA (Ceccoli & Hixon, 2012). According to Ammann (2014) EU legislation for the approval of GM crops is one of the most restrictive in the world. Some countries, such as Switzerland (Siegrist, 2000), have actually banned aspects of GM technologies on the basis of public concern. In addition to regulatory issues, the success of GM products on the market depends upon public acceptance (Moschini, Bulut & Cembalo, 2005). If this hostility is based on uninformed prejudice, it can be considered as blocking the development of potentially important technologies. Thus, an understanding of the determinants of perceptions of GM technologies is important.

The standard economic approach to analysing individual attitudes and actions, tends to assume that people will support an action if it is in their perceived self-interest to do so, i.e. if the gains are greater than the costs, including the risks. The literature on GM foods tends to extend these costs and gains away from the individual and their family, to the wider community (Umberger, Thilmany, McFadden & Smith, 2009). Boxal and Adamowicz (2002) developed the traditional model to include psychological factors. Also from a psychological perspective, Siegrist (2000) concluded that perceived benefit and risk determined the acceptance of gene technology in Switzerland.

Three meta studies on attitudes to GM foods (Dannenberg, 2009; Frewer et al., 2013; Lusk et al., 2005) all conclude that there are substantial differences between European and American consumers, with the latter more hostile than the former. There has been some work done on contrasting attitudes to perceived risk. Grunert et al. (2000) found British consumers to be more negative to genetic modifications related to animals than to plants. Burton et al. (2001) found significant differences in consumer attitudes to cisgenesis and transgenesis, and that women were significantly more averse to both technologies than men. Similarly, both Baker & Burnham (2001) and Siegrist (2000) suggested that women are more risk averse than men, and more concerned with food safety. Barrena & Sanchez (2010) found that risk perceptions in food products, the health impact of foods, and individual age and income, were the main variables in explaining consumers' decisions. The importance of socio-economic variables in explaining risk and benefit perceptions to GM foods was further confirmed by Bredahl (2001) and Schläpfer (2008). Both Flynn, Slovic & Mertz (1994) and Grimsrud et al. (2004) also found socio-economic characteristics to be important, with positive attitudes toward GM food being linked to the young and males.

The results on the impact of education and scientific knowledge have been mixed. Grimsrud et al. (2004) concluded that both self-reported knowledge about biotechnology and higher levels of formal general education, increased acceptance of GM food in Norway. Ceccoli & Hixon (2012) also emphasised the importance of scientific knowledge in looking at attitudes toward GM foods in 15 EU member states and Flynn, Slovic & Mertz (1994) concluded that scientific understanding influenced individual risk perception. However, Schläpfer (2008) found no evidence linking education and positive attitudes to GM crops.

There has been considerable work done on the impact of religion on attitudes. Costa-Font & Mossialos (2006) found religiosity to be significant in determining attitudes to cisgenesis. Myskja (2006) observed that religious groups emphasise that crossing species was unnatural. He also emphasised that there have been a lot of religious pronouncements on GM foods. More generally Wilkes, Burnett & Howell (1986) found religiosity to impact on consumer behaviour and Brossard et al. (2009) argued that life styles and knowledge about technology tend to be interpreted through the 'lens of religious beliefs'. Biel & Nilsson (2005) found a significant impact of religion on attitudes to GM, but not on other environmental issues.

Several studies have analysed the impact of perceived risks and gains on overall attitudes and decisions. Mazzocchi et al. (2008) found that food scare risk perceptions and trust were important determinants of food purchases in several EU countries. Hu et al. (2004) linked consumers´ preferences for GM food to risk attitudes. The literature on attitudes to biotechnology in general and GM foods in particular also encompasses environmental concerns (Moon & Balasubramanian, 2001; Lockie et al., 2005) and concerns about 'the naturalness' of the technology (Umberger, Thilmany McFadden & Smith, 2009; Nistor, 2012). More generally, naturalness, or rather loss of naturalness, as an element of risk perception, has been central in the risk field since the 1970's (see e.g. Slovic, 1986). Building upon this, in the general context of food safety including GM foods, Fife-Shaw & Rowe (1996) noted people's frequent reliance on a "natural-is-good'' heuristic. Rozin, Fishler & Shields-Argeles (2012) suggested that naturalness may appeal to those who resent the intrusion of technology into basic traditions. Finally, Kontoleon & Yabe (2006) emphasised the importance of ethical concerns, environmental concerns, trust and education in the demand for GM derived animal foods in the UK. Trust does appear to be an important concept and Siegrist (2000) found it to impact on perceptions of risks, benefits and the overall acceptance of gene technology.

There has also been some work done on the specific attitudes of farmers to GM foods. Areal, Riesgo & Rodriguez-Cerezo (2011) concluded that, for EU farmers, the potential financial gains were important in the decision to adopt GM herbicide-tolerant crops, as did Breustedt, Muller-Scheeßel, & Latacz-Lohmann (2008) for German arable farmers adopting GM oilseed. However (Guehlstorf, 2008) in a study in the USA, concluded that farmers were influenced by environmental considerations and social impact, as well as financial gains.

In this paper we examine the determinants of attitudes to GM foods in more depth than has been done previously, focusing on the extent to which they are linked to socio-economic and demographic characteristics as well as on the impact of both the individual's religion and scientific background. The study is done within the context of two different biotechnologies related to gene transfer in apples. The production of a new apple cultivar normally takes at least 15–20 years and costs €400,000 (Fenning & Gershenzon, 2002) and even longer if a trait, such as disease resistance, is introduced from wild apple species. Thus, 50 years or more are necessary to obtain a new apple cultivar expressing a trait originally present in a wild apple (Flachowsky et al., 2011). Gene transfer technologies can significantly shorten this time. There has been relatively little work specifically relating to people's attitudes to GM apples. However, Schenk et al. (2008) studied consumer risk and benefit perception of GM applied to apple cultivars, within the context of allergies. They conclude that acceptance of GM products is primarily a function of perceived personal benefit as opposed to personal or environmental risk perceptions per se.

Thus the existing literature indicates that people appear to be weighing up the advantages and disadvantages of GM food, with these extending beyond a simple comparison of individual based risks and benefits. One question is whether concepts of perceived naturalness and environmental impact are separate from risks and benefits? We shall assume that this is the case, but also go some way to testing this assumption. Although it is often not treated as such, the process can be interpreted as a mediation model, where concepts such as risk and benefits determine overall attitudes, and the former are in turn determined by a number of socio-economic and country specific factors.

Insert Fig 1 about here

Fig. 1, which adapts the figure found in Costa-Font, Gil & Traill (2008), captures the essential features of our model. Perceived risk, benefits etc. are a function of socio-economic and other variables, and overall attitudes are determined, as in a mediation model, by these perceived impacts. There is still a role for socio-economic variables to have an independent impact on overall attitudes, e.g. through their impact on trust, which is not explicitly included in the empirical analysis. Scientific knowledge is reflected in an individual's education and their family background. We model the latter by the scientific background of the respondent's parents. Knowledge may also be linked to age, since with age individuals accumulate knowledge (Costa-Font & Mossialos, 2006), but, on the other hand, formal knowledge learned at school may become obsolete.

Not all of the variables in Fig. 1 are included in the empirical model. This is the case for the regulatory institutions in the top row and trust in the third row. They are included in Fig. 1 because they are important aspects of the process, but it is not always possible to include every theoretical variable in an empirical model as we are restricted by data availability. Thus, in the empirical analysis the actions of the countries' regulatory institutions are captured by the country dummy variables, which of course also reflect other country characteristics. Trust will also be captured by these variables and in addition, as indicated in Fig. 1, by socio-economic variables (Schoon & Cheng, 2011). Nor are the variables in the second row explicitly captured in the model. They are the implicit route by which the socio-economic, demographic, educational and religious and scientific background variables impact upon the attitudinal variables. In further research it would be valuable to model this process by explicitly including the second row variables in the empirical analysis, provided they can be satisfactorily measured, which may not always be the case.

Combining both the literature review and the model presented above, we argue that socio-economic and demographic variables impact on underlying attitudes to perceived risk, benefits, environmental impact and naturalness. These underlying variables will then impact on overall attitudes. Also influencing attitudes will be education, scientific background and religion. Finally the literature suggests people tend to view cisgenesis more favourably than transgenesis (McComas et al., 2014). More formally, we are testing the following hypotheses within the specific context of apples:

- Socio-economic variables, scientific knowledge and background, religion and education impact both on perceptions of the risks and gains related to GM food and on the perceptions of naturalness and environmental impact.
- Overall approval of GM foods depends upon the relative risks and gains, and also on the perceptions of naturalness and environmental impact of the technology.
- People in general are more favourable to cisgenesis than transgenesis.

Methods and data

Modelling attitudes to risks and gains from GM technologies

Stage one of the modelling process relates to attitudes to risks and gains. There is the risk to the individual and their family from the production of the food, the risk related to eating the food and the production and consumption risk to everyone else. The perceived risk to the individual from the production may be greatest for those living in rural areas, potentially close to farms producing GM foods. Risk perceptions may also differ with age, marital status and whether an individual has children (Barrena & Sanchez, 2010). The definition of gains follows a similar logic, but may exclude gains from actually eating GM food.[1] For many individuals a lower price is an important factor in the personal gains stemming from the new technology (Umberger, Thilmany, McFadden & Smith, 2009) and thus family size and income may be important in determining the extent of these gains. The gains, as well as the risks, will be potentially wider for some individuals, e.g. those engaged in the food industry, including farmers themselves not all of whom will use GM crops (Breustedt, Muller-Scheeßel, & Latacz-Lohmann, 2008). There are also the perceived potential benefits to the economy.

As discussed above, knowledge is likely to be an important determinant of attitudes (Baker and Burnham, 2001). Following the earlier discussion, it can be reflected in the individual's level of education per se, their scientific background, their age and religion. Thus, perceptions are assumed to be functions of socio-economic variables ($\mathbf{X}_i$), knowledge variables ($\mathbf{K}_i$) and country specific variables ($\mathbf{C}_i$):

$$y_{ki} = f_k(\mathbf{X}_i, \mathbf{K}_i, \mathbf{C}_i) + \varepsilon_{ki} \qquad (1)$$

Where y_{ki} equals perceived gains (G_i), risks (R_i), environmental impact (E_i) or naturalness (N_i). ε_{ki} is an error term, reflecting factors unique to the individual. Country dummy variables capture differences in the importance of agriculture for the economy and the (perceived) quality of the regulatory infrastructure.

The left hand side variables in (1) are continuous variables reflecting underlying levels of perceived risks, etc. However, the data we use are ordered in four categories, e.g. ranging from total disagreement that it is risky to total agreement. The response is in the j th category if:

$$\alpha_{j-1} < y_{ki} < \alpha_j \qquad j = 1,2,3,4 \qquad (2)$$

Dropping the k subscript, we define $Z_{i,j} = 1$ if y_i is in j th category, and $Z_{i,j} = 0$ otherwise. The probability that $Z_{i,j} = 1$ is:

$$\Pr(Z_{i,j} = 1) = \Phi(\alpha_j - f(X_i, K_i, C_i)) - \Phi(\alpha_{j-1} - f(X_i, K_i, C_i)) \qquad (3)$$

where Φ is the cumulative standard normal distribution for the error term. This implies that if we linearise the functions we can estimate both the coefficients and the dividing points (α_j) between the different categories by ordered probit. Ordered probit is widely used in analysing

[1] Unless it is believed that GM food will actually taste differently, last longer, or through reduced use of pesticides, potentially be healthier than non-GM food. In this context we note that Schenk et al. (2011) found a clear gain for those with fruit allergies in the actual eating of GM apples.

attitudinal data of this kind. It shares the advantage with ordinary least squares (OLS) that it identifies statistically significant relationships between a set of explanatory variables and an independent one. But unlike OLS, it allows for unequal differences between ordinal classes in the dependent variable (Greene, 2012).

Modelling overall attitudes from GM technologies

In the second part of our analysis we examine overall attitudes to the GM technologies. The individual will 'approve' of the technology, if the gains outweigh the risks:

$$A_i = \pi_1 G_i - \pi_2 R_i - \pi_3 E_i + \pi_4 N_i \qquad (4)$$

where π_1, π_2, π_3 and π_4 denote the weights applied to G_i, R_i, E_i and N_i respectively, in determining overall approval. G_i, R_i, E_i and N_i are all expressed in comparable terms such as monetary value. An increase in E_i represents an increase in (harmful) environmental impact. N_i is defined in such a way as to increase with perceived naturalness. It might be argued that both unnaturalness and environmental impact, particularly the former, are sub-categories of risk and hence there is no need to enter them separately into (4). However our approach is consistent with part of the literature which has put special emphasis on these two concepts (Moon & Balasubramanian, 2001; Umberger, Thilmany McFadden & Smith, 2009). Perceived naturalness is not so much a risk, but a perception that it goes against natures laws and is therefore wrong (Biel & Nilsson, 2005). The risks have tended to focus on the risks to individuals of GM food. The environmental risks are more a global concept and Hu et al. (2004) even examine the trade-off involving potential environmental benefits in food. Hence we assume that these are different concepts to risk per se as individuals tend to interpret the term, and this is a hypothesis we will be testing.

The survey data

Insert Table 1 about here.

We use the data from the Eurobarometer survey 73.1 on biotechnology, science and technology carried out in January/February 2010. These surveys are widely used in analysing people's attitudes and indeed have been used by Christoph, Bruhn & Roosen (2008) to analyse attitudes to GM foods in Germany. The survey covers the population of the EU member states aged 15 years and over, although we restrict our analysis to those aged between 18 and 97.[2] The average number of observations in the sample used is about 12,000. This is less than the 15,650 respondents due to missing observations for some variables, caused by 'no answers' and 'don't knows'. The variables are defined in Table 1 of the paper. The five dependent variables relate to the perceived gain, risk, environmental impact and naturalness of the two technologies, together with whether they should be encouraged. The latter we use as a measure of overall approval as it relates to an overall view of whether the technology should be pursued with, given the specific risks and gains. In reaching a view on whether it should be encouraged, the individual needs to balance all of the impacts. The specific questions asked and the coding are specified in Table 1.

The dependent variables in our regression analysis relate to attitudes to the introduction of two resistance genes in apple trees to make them resistant to mildew and scab. The first is a gene that exists naturally in wild/crab apples and the second one is injected from another species such as a bacterium or animal into an apple tree. These are examples of cisgenesis and transgenesis respectively. The independent variables relate to an individual's socio-economic characteristics and include variables which reflect an individual's knowledge and self-interest. Income is not included because the data is not available. Instead variables which proxy it, such as difficulties relating to paying bills, consumer durables and whether a manual worker, are included. If we simply include age per se, it implies its impact is linear. This may not be the case as the difference between 30 and 20 year olds may not be the same as that between 60 and 50 year olds. We could include the log of age, but including age as a quadratic allows for the impact to have a turning point. This approach is common in regression analysis on survey data involving age.

Results

Summarising the data

Insert Table 2 about here.

Table 2 shows that 57.1% of respondents approved, i.e. wished to see it encouraged, of cisgenesis and 31.4% of tranesgenesis. The figures suggest that the public regards transgenesis as a riskier and more unnatural intervention. Most people perceive potential gains from the two

[2] Eurobarometer surveys are carried out by TNS Opinion and Social Consortium at the request of the European Commission. The basic sample design is a multi-stage, random probability one. The surveys are designed to be representative in terms of the distribution of the resident population of the respective EU nationalities with respect to metropolitan, urban and rural areas. All interviews are face to face, in people's homes and in the national language.

interventions. But there are also perceived risks and impacts on the environment, as well as the perception that such interventions, even cisgenesis, are unnatural. The four basic attitudinal variables relating to risks, gains, environmental impact and naturalness are correlated, for example the correlation between perceived environmental impact and risks for cisgenesis is 0.72 and transgenesis is 0.50. Other correlations are lower. This suggests that people's attitudes are linked, but it also suggests that the link is not perfect, that there are substantial variations in different attitudes and it is these differences, which make the regression analysis meaningful.

In terms of socio-economic characteristics, Table 2 shows the percentage of people approving of both technologies is considerably greater for men than women, increases with the level of education, is slightly higher for younger compared to older people and for those who do not live in rural areas. Support also tends to be slightly larger for farmers. In many cases these are significant differences from the rest of the sample as the Table shows.

Insert Table 3 about here.

Table 3 summarises attitudes across different religious and scientific family backgrounds. There are substantial differences, particularly for cisgenesis, with Muslims, and to a lesser extent Catholics, tending to be more hostile. There are still larger differences relating to scientific background and having a father with a scientific background is associated with much more favourable attitudes to these technologies[3]. Religion may in part be picking up country characteristics, but the following regression analysis points to the substantial differences between countries even when allowing for individual characteristics such as religion. Fig. 2 shows the distribution of attitudes for cisgenesis on the right hand side of the diagram and on the left hand side, for transgenesis. There are clearly substantial differences between the two technologies and across countries. Majority support for cisgenesis tends to be rare in any country, but in Finland, Hungary and Slovakia people are substantially less hostile towards it than in Sweden, Luxembourg, France and Germany. Attitudes to transgenesis tend to be consistently less favourable. This, e.g., can be seen very clearly for Hungary.

Insert Fig. 2 about here.

Socio-economic determinants of attitudes to risks and gains

Insert Table 4 about here.

[3] Notwithstanding the small numbers involved, as the Table shows such people hold significantly different attitudes to the rest of the population for all attitudes other than for environmental impact.

Table 4 shows the regression results related to people's basic attitudes to apple cisgenesis, i.e. to the introduction of resistance genes from crab apples, which grow in the wild. The independent variable is discrete and ordered and thus, we use ordered probit regression. This is the case for all the regressions in this paper. The possibility exists that the variables may be correlated with multicollinearity being a problem, particularly, for example, with respect to the country and religious dummy variables. However, the highest variance inflation factor (vif) is 4.23, well below the critical value of 10 which is commonly used for this test. Column 1 shows the results for overall approval. It is significantly greater for men, and increases with the level of education. It is greater for the unemployed and manual workers and increases with prosperity, as reflected by the impact of the variables relating to consumer durables and the ability to pay bills. However, widowers, Muslims, Catholics and Orthodox Christians are significantly less approving. In the other regressions, variables relating to men, consumer durables, education, Muslims, Catholics, Orthodox Christians and the ability to pay bills are consistently significant with an impact on attitudes similar to their impact on approval, e.g. the characteristics which tend to increase approval also tend to reduce perceived risks. Thus, perceived risk declines with education and is lower for males, whilst Muslims are less favourable on all dimensions. Age is only significant for considerations of whether this technology is 'natural'. As people age they are increasingly more likely to accept it to be natural until they reach the age of approximately 62. Farmers are significantly different from others only in one respect - they are more likely to perceive the technology as natural, as shown in the fourth regression in Table 4. Representatives of other religions consist predominantly of Protestants and this variable is never significantly different from those who profess no religion, who represent the default case, nor are Protestants significant when included as a separate variable.

The effects of studying science at a higher level are analysed separately for men and women. Both are more favourable of the technology. But for women this is only the case for overall approval and the perceived gains. Both men and women's attitudes are also impacted upon by whether their father had studied science at a higher level.[4] The impact varies between men and women, but always in a manner favourable to the technology. However in Table 4, there is not a significant impact from whether the mother had studied science in any of the regressions.

Insert Table 5 about here

In Table 5 we examine attitudes to apple transgenesis. Here we focus on the differences compared to the results in Table 4. Firstly, the age of respondents is significant in all five

[4] See Table 1 for the exact definition of this and other variables.

regressions. As people age, they tend to become less favourable to this technology. Higher achieved education also reduces people's perception of risk, and is again significant with respect to overall approval and perceptions of gains as in Table 4. The unemployed, manual workers and widowers are no longer significantly different to others. Orthodox Christians are significantly different from others in terms of overall attitudes, perceived risk and environmental impact. Muslims are significantly different to others, only in the perception of this technology as less natural and Catholics in terms of its environmental impact. The significance of other variables, e.g. being a male, the number of consumer durables owned, ability to pay bills, are largely similar to the results in Table 4. Farmers are now different to others in their perception of gains, rather than the perceived naturalness of the technology. Studying science at a higher level makes people more favourable to this technology although more so for men than women. Finally, having a father, who studied science, impacted favourably on attitudes, although again more so for men than women. There is again little impact from having a mother who studied science. In both sets of regressions, scientific background as well as religious affiliation impacted upon perceived naturalness, but also other attitudinal variables.

We pooled the two regressions for risk and included each explanatory variable twice, once for the whole pooled sample and once for just the cisgenesis part of the sample. We do not show these regressions, but significant differences are shown in Table 5 via the symbols alongside the t statistics. Age and age squared were significantly different in their impact on the two technologies, as was gender, the variable relating to Muslims and whether the respondent studied science for both males and females. Many of the dummy variables relating to countries were also significantly different. Overall the two sets of variables were significantly different. This confirms our earlier suspicions, that although there are similarities in the qualitative impact of the different variables on attitudes to the two technologies, there are significant differences in the exact quantitative impact. We repeated this for the other four regressions relating to benefits, naturalness, impact on the environment and overall attitudes. In some respects the most significant differences in terms of impact on the two technologies were for the Islamic variable which was significantly different in regressions for the environment, naturalness and overall attitudes at the 1% level of significance, and very nearly significant at this level in the other two equations. There were also many different impacts with respect to the country variables. The nature of these differences can be seen by comparing Tables 4 and 5. For example, age has much more of an impact on transgenesis than cisgenesis across virtually all dimensions.

Balancing risks and gains

Table 6 shows the results of regressing overall attitudes on the attitudinal variables relating to risk, gain, environmental impact and perceived naturalness. The dependent variable is overall approval, as defined in Table 1. The risk variable is significant in both cases, the more risky an individual perceives the technology to be, the less likely they are to approve of it. This is then balanced by the perceived gains. The relative impact differs between the two technologies, with the marginal effects relating to risk being greater in the transgenesis regression. But the marginal effects relating to perceived gains, environmental impact and naturalness are much lower in this regression. This suggests that for genes extracted from other apples, the perceived risk is a less important factor in determining overall approval than for transgenesis. Socio-economic variables were not significant, when added to the regressions shown in Table 6 for transgenesis. They were significant, however, for the cisgenesis regression. The country dummy variables were jointly significant in all regressions in Tables 4, 5 and 6.

Insert Table 6 about here.

Given certain assumptions, in a linear mediation model the impact of a socio-economic variable (X) is the combination of two effects: (i) the impact of X on the mediations and (ii) the mediations on Y. If X is also included in the final equation then this direct impact needs to be taken account of too. Similarly the combined variance is linked to the variances, and covariances, of the separate coefficients. However, we are using ordered probit for both sets of equations and the interpretation and analysis is not so straightforward. It is still possible by looking at the first columns of Tables 4 and 5 to find the overall significance and impact of individual socio-economic variables on overall attitudes. In addition, for example, by examining the signs and significance of the coefficients in Tables 4 and 5 with risk as the dependent variable, along with the impact of risk on overall attitudes in Table 6, we can also gain an understanding of the nature of that impact.

Discussion

We have confirmed the three main hypotheses we were testing. Firstly that people's attitudes respond to a variety of influences, including socio-economic variables, scientific knowledge and background, religion and education. Secondly that overall approval of GM foods depends upon the relative risks and gains, and also on the perceptions of naturalness and environmental impact of the technology. Finally that people in general are more favourable to cisgenesis than transgenesis. In doing this, we have confirmed the findings of the literature (e.g. Bredal, 2001; Schläpfer, 2008; Barrena & Sanchez, 2010) that socio-economic and demographic variables such as age determine attitudes to GM foods. In addition, our analysis has confirmed that there are significant differences in the impact of these variables on attitudes to the two technologies. In interpreting the impact of these variables it is useful to refer to Fig. 1. Thus, it could be that women have different attitudes, e.g. to risk aversion, or that they have a different knowledge set to men.

The results with respect to scientific background are consistent with those of Ceccoli & Hixon (2012) and Grimsrud et al. (2012) who find knowledge of science increased willingness to accept GM foods. As Ceccoli & Hixon point out, an understanding of science helps increase an individual's understanding of the scientific issues underlying GM foods, and it may be the corresponding reduction in uncertainty which helps to increase approval. Our results suggest that informal exposure to science via family background can also affect attitudes as well as more formal education. A number of reservations should be made in connection with this. Firstly, as indicated in Table 3, we have relatively small numbers of people, particular for parental influence, although despite this, their views are in several cases significantly different to others in both this Table and the regressions which follow. Secondly, it is also possible some others, e.g. those whose parents studied economics, might share similar views to those whose parents studied science.

We also confirm the results of others in that, even after taking account of individual characteristics, there are significant differences in attitudes between people in different countries to both technologies. Finally, we find evidence that perceptions of risks and gains combine together to determine overall attitudes, along with perceptions of the naturalness and environmental impact of the technology. This suggests that the latter two cannot be simply combined with risks and gains, but are to an extent separate dimensions. But again attitudes are not homogenous across the two technologies, with risks being more important for transgenesis than cisgenesis.

From a policy perspective these findings are important, if governments believe that at least some of these technologies present no risk to individuals or the environment, but they are prevented from being developed by public hostility.[5] The conclusion that attitudes are determined by other factors than a simple calculation of perceived gains and risks may present particular difficulties for a government wishing to persuade its citizens of the benefits of this new technology. These difficulties are further compounded by the long-lasting influences on individuals, as reflected by the influence of the parent's scientific background on individual perceptions. In this respect attitudes may be slow to change. However, the results in emphasising childhood influences also suggest that an emphasis on technology study at schools may help shape the attitudes of future generations, and thus may pay dividends in the future.

[5] There is the evidence that this is the case in the UK.
See: http://www.guardian.co.uk/environment/2013/jun/20/owen-paterson-uk-global-leaders-gm-crops .

The results also suggest that policy makers should guarantee the dissemination of GM scientific knowledge in order to assure a high level of objective knowledge among the population. Furthermore, the evidence suggests that people's attitudes to biotechnology are influenced by their religious background. Hence, a dialogue with religious leaders may also help to change opinions. The significance of the country dummy variables may indicate the role of institutional quality and potentially trust affecting both basic attitudes to risks and gains, and also how they are traded off in determining overall approval. This emphasises the importance of the regulatory agencies' institutional quality in promoting acceptance of new technologies. In addition, differences in attitudes to cisgenesis and transgenesis supports the argument of Schouten, Krens & Jacobsen (2006) that the two should not be subject to the same regulatory approach. It also suggests that EU biotechnology companies may initially at least direct their research and development efforts more towards cisgenesis. Finally, the diversity of attitudes between EU countries makes arriving at a common position difficult, as does the diversity of views within countries.

Some limitations to the research need to be mentioned. We used various proxies for income, but clearly it would have been better to have income itself. Secondly although our sample size of approximately 12,000 is not small, a larger sample would allow us to explore more subtleties in the nature of the impact of our variables. For example, does the impact of religion on attitudes vary with age? Finally in further research a greater focus on the exact nature of the perceived risks and gains would be valuable. It would also be interesting to understand the rationale for some of these effects more. The finding that the young differ from older people is consistent with the literature, but more focused research on why this is the case would be valuable. Similarly we have linked the fact that Muslims and Catholics have different attitudes to those from other religions to the teachings of religious leaders and the extent to which individuals follow those teachings. More detailed information on this would again be useful, together with results from other countries than those in the EU.

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Table 1
Data definitions

Endogenous Variables	
Apple Cisgenesis: Attitudes to artificially introduce a gene that exists naturally in wild/ crab apples which provides resistance to mildew and scab:	
Encouraged/ Approval	Coded 1 (totally disagree that it should be encouraged) to 4 (totally agree). In the analysis we assume that this is a proxy for overall approval.
Gain	Coded 1 (totally disagree that 'it will be useful') to 4 (totally agree).
Risk	Coded 1 (totally disagree that it is risky) to 4 (totally agree)
Environment harm	Coded 1 (totally disagree that it will harm the environment) to 4 (totally agree)
Natural	Coded 1 (totally agree that it's fundamentally unnatural) to 4 (totally disagree)
Apple Transgenesis: Attitudes to artificially introducing a resistance gene from another species such as a bacterium or animal into an apple tree to make it resistant to mildew and scab:	
Encouraged	Coded as for cisgenesis
Gain	Coded 1 (totally disagree that 'it's a promising idea') to 4 (totally agree).
Risk	Coded 1 (totally disagree that eating such apples will be safe) to 4 (totally agree)
Environment harm	Coded as for cisgenesis
Natural	Coded as for cisgenesis
Exogenous Variables (binary variables, coded 1 or 0 unless otherwise stated)	
Scientific Background (coded separately for male and female respondents):	
Father/mother	Coded 1 if their father/mother have a job or a university qualification in natural science, technology or engineering.
Respondent	Coded 1 if the respondent studied natural science, technology or engineering at university or college.
Socio-Economic Variables	
Male	Coded 1 if the respondent is male.
Age	Age of the respondent (in years).
Village	Coded 1 if the respondent lives in a rural area or village.
Town	Coded 1 if the respondent lives in a small or middle sized town.
Married	Coded 1 if the respondent is either married or living with a partner.
Children	Coded 1 if the respondent lives with children.
Religion	A set of variables coded 1 if the individual is a member of that religion. Other religions are primarily protestants.
Manual worker	Coded 1 if the respondent is a manual worker.
Farmer	Coded 1 if the respondent is a farmer.
Unemployed	Coded 1 if the respondent is unemployed.
Education	Age at which the respondent finished full time education. Coded: 1, if aged <16 years; 2 if aged 16-19 years; 3 if aged >19 years.
Pay bills	Difficulties in paying bills in the previous year, responses range from 'most of the time' (coded 1) to 'almost never' (coded 3).
Consumer Durables	The number of consumer durables (from: TV set, DVD player, CD player, Computer, etc.) durables owned.

Note: The preamble to the questions relating to the endogenous variables mentioned new ways of controlling common diseases in apples. It then expanded on this: "The first way is to artificially introduce a resistance gene from another species such as a bacterium or animal into an apple tree to make it resistant to mildew and scab. For each of the following statements about this new technique please tell me if you agree or disagree." Then followed the separate questions relating to risk, gains, etc. A second set of questions followed: "The second way is to artificially introduce a gene that exists naturally in wild/crab apples which provides resistance to mildew and scab…." These therefore relate to transgenesis and cisgenesis respectively.

Table 2
Attitudes to the Technologies across Socio-economic-demographic variables

	All	Age<40	Age≥40	Village	Town	City	Male	Female	High Education	Average Education	Low Education	Farmer	Pay bills
Number	15650	5385	9754	5532	9962	5688	7318	8332	6356	6387	2907	189	9126
Cisgensis													
Approval	57.1	58.0	56.4	54.7**	58.3*	58.8*	60.3**	54.3**	61.2**	59.1**	55.8**	59.1	58.1*
Risk	44.8	45.7	44.2	45.9	43.2**	45.5	43.1**	46.4**	44.8	40.0**	47.1**	45.7	43.1**
Gain	72.4	73.2*	71.5*	70.6**	73.3	73.7*	74.7**	70.4**	77.9**	76.9**	69.5**	70.2	74.8**
Environment	35.2	35.6	35.1	37.3**	33.4**	34.9	33.3**	37.0**	34.6	31.8**	36.9**	36.3	32.9**
Natural	44.3	43.3	44.8	42.5**	44.9	45.7*	46.4**	42.4**	43.2	46.7**	43.3**	49.7	45.1**
Transgenesis													
Approval	31.4	34.7**	29.2**	29.5**	32.8**	32.2	36.4**	27.0**	39.4**	32.7*	29.5**	35.1	32.3*
Risk	64.7	61.6**	66.6**	67.0**	62.8**	64.3	59.4**	69.5**	58.5**	61.6**	67.3**	56.3*	62.9**
Gain	47.7	52.0**	44.6**	46.0**	49.2*	48.1	52.8**	43.0**	59.7**	50.3**	44.3**	55.2	49.1**
Environment	57.2	54.8**	58.8**	58.3*	56.1	57.0	53.5**	60.5**	53.6*	56.4	58.2**	56.1	55.8**
Natural	20.5	22.4**	19.5**	19.6*	20.9	21.3	22.9**	18.4**	21.9	21.6*	19.6**	24.2	20.5

Note: The proportions show those agreeing (totally or partially) with the statements that the technology (i) should be encouraged, which we link to approval (ii) is risky, (iii) provides benefits, (iv) harms the environment and (v) is natural. These concepts are defined in Table 1 for each technology. **/* denotes a significant difference to the rest of the sample at the 1%/5% levels of significance. Numbers in first row denote number of people, e.g. 7318 males.

Table 3

Attitudes to the Technologies across Religion and Scientific backgrounds

	Religion Muslim	Catholic	Orthodox	Other	None	Studied science Respondent	Father	Mother
Number	591	6156	1876	3018	4009	3006	436	296
Cissgenesis								
Approval	40.6**	53.7**	60.9**	59.9**	60.4**	61.8**	67.2**	64.0*
Risk	62.5**	49.8**	40.5**	39.8**	40.8**	42.6**	34.4**	42.0
Gain	56.4**	69.3**	70.2*	78.0**	75.8**	77.5**	78.3**	78.1*
Environment	56.1**	39.8**	36.2	28.5**	30.7**	32.9**	31.9	38.6
Natural	33.3**	39.1**	51.6**	48.3**	47.1**	46.5**	51.9**	54.0**
Transgenesis								
Approval	30.7	31.2	23.3**	32.4	34.7**	38.2**	43.2**	43.7**
Risk	67.1	65.6	75.2**	60.9**	61.4**	57.3**	48.5**	49.8**
Gain	46.8	47.4	39.6**	49.3	50.6**	56.5**	61.3**	58.5**
Environment	60.9	57.6	67.1**	55.1*	53.5**	53.9**	55.8	55.0
Natural	26.9**	19.7*	19.3	20.4	21.7*	23.2**	27.9**	32.1**

Note: See Table 2

Table 4

Regression Results: Attitudes to Apple Cisgenesis Technology

	Encouraged/ Approval	**Risk**	**Gain**	**Natural**	**Environment harm**
Age	0.00653	-0.00446	-0.00199	0.0132**	-0.00134
	(1.90)	(1.31)	(0.58)	(3.97)	(0.38)
Age^2(x100)	-0.00532	0.00193	0.00388	-0.0107**	-0.00100
	(1.50)	(0.55)	(1.10)	(3.12)	(0.28)
Male	0.11850**	-0.0531*	0.1022**	0.0537*	-0.0698**
	(5.25)	(2.38)	(4.58)	(2.46)	(3.04)
Village	-0.00892	-0.0277	-0.0172	-0.0149	0.00160
	(0.35)	(1.09)	(0.67)	(0.60)	(0.06)
Town	0.0470	-0.0717**	0.0232	0.0354	-0.0585*
	(1.87)	(2.88)	(0.93)	(1.46)	(2.29)
Education	0.0411*	-0.0678**	0.0787**	0.0655**	-0.0373*
	(2.49)	(4.15)	(4.83)	(4.11)	(2.22)
Unemployed	0.0835*	-0.0534	0.0745	0.0896*	-0.0901*
	(2.13)	(1.38)	(1.93)	(2.38)	(2.26)
Manual	0.0553*	-0.0105	0.0300	0.0677**	-0.0187
	(2.11)	(0.40)	(1.16)	(2.66)	(0.70)
Married	-0.0433	0.0106	-0.0385	-0.0436	0.0343
	(1.72)	(0.42)	(1.54)	(1.79)	(1.34)
Widow	-0.0952*	0.0438	-0.0992*	-0.0873*	0.0952*
	(2.15)	(1.00)	(2.25)	(2.04)	(2.10)
Children	-0.0450	0.00377	-0.00543	-0.0372	-0.00129
	(1.93)	(0.16)	(0.24)	(1.65)	(0.05)
Muslim	-0.2236**	0.3530**	-0.1900**	-0.2482**	0.4490**
	(3.37)	(5.47)	(2.97)	(3.90)	(6.84)
Catholic	-0.0880**	0.0850**	-0.0865**	-0.0893**	0.0949**
	(3.12)	(3.02)	(3.80)	(3.26)	(3.29)
Orthodox	-0.1267*	0.1868**	-0.0949	-0.0897	0.1449*
	(2.02)	(3.07)	(1.56)	(1.49)	(2.31)
Other religion	0.0280	0.0110	0.0405	0.00527	-0.0111

	(0.91)	(0.35)	(1.30)	(0.17)	(0.35)
Pay bills	0.0383*	-0.0389*	0.0613**	0.0561**	-0.0529**
	(2.41)	(2.47)	(3.90)	(3.64)	(3.27)
Consumer durables	0.0618**	-0.0515**	0.0621**	0.0354**	-0.0667**
	(5.53)	(4.64)	(5.61)	(3.27)	(5.83)
Farmer	0.1727	0.0203	0.1160	0.2061*	-0.0898
	(1.91)	(0.23)	(1.29)	(2.39)	(1.00)
Impact on Men of studying science					
Father:	0.1317	-0.1551	0.0754	0.1922*	-0.1057
	(1.64)	(1.93)	(0.92)	(2.46)	(1.29)
Mother:	0.0945	0.1211	-0.0269	0.1342	0.2151*
	(0.89)	(1.15)	(0.25)	(1.28)	(1.98)
Respondent	0.1265**	-0.0751*	0.1293**	0.0786*	-0.0703
	(3.46)	(2.06)	(3.53)	(2.21)	(1.89)
Impact on Women of studying science					
Father:	0.2643**	-0.0945	0.2057*	0.0403	-0.0116
	(2.99)	(1.08)	(2.33)	(0.47)	(0.13)
Mother:	-0.0302	-0.0823	0.00082	0.1462	0.0344
	(0.30)	(0.83)	(0.01)	(1.47)	(0.33)
Respondent	0.1319**	-0.0429	0.1861**	0.0416	-0.0677
	(3.57)	(1.17)	(5.05)	(1.16)	(1.80)
3rd Threshold (α_1)	-1.513	-0.3196	-1.195	0.0737	-0.6725
2nd Threshold (α_2)	-0.4517	0.5966	0.0166	0.9198	0.1368
1st Threshold (α_3)	0.2059	1.656	0.611	1.812	1.261
Observations	12405	12476	12940	13252	11983
Log Likelihood	-16422	-16268	-16003	-17644	-15295
X^2	576.1	558.8	631.3	671.9	615.8

Note: Regressions estimated by ordered probit. Standard errors were corrected for heteroscedasticity, The coefficients in parentheses denote t statistics, the number above relates to the regression ccoefficient, **/* significance at the 1/5% levels. Country fixed effects included, but not shown. The coefficient on age has been multiplied by 100 for purposes of comparability.

Table 5
Regression Results: Attitudes to Apple Transgenesis Technology

	Encouraged/ Approval	**Risk**	**Gain**	**Natural**	**Environment harm**
Age	-0.0153**	0.0147**	-0.0222**	-0.00718*	0.0115**
	(4.38)‡‡	(4.13)‡‡	(6.52)‡‡	(2.07)‡‡	(3.22)‡
Age^2(x100)	0.0123**	-0.0128**	0.0198**	0.00423	-0.0100**
	(3.60)‡‡	(3.46)‡‡	(5.63)‡‡	(1.18)‡‡	(2.71)
Male	0.2002**	-0.1806**	0.1893**	0.1186**	-0.1307**
	(8.66)‡	(7.73)‡‡	(8.51)‡‡	(5.20)‡	(5.60)
Village	-0.0425	0.0142	-0.00373	-0.0228	0.0207**
	(1.61)	(0.53)	(0.15)	(0.87)	(0.78)
Town	0.0183	-0.0320	0.0375	-0.00248	-0.00756
	(0.71)	(1.23)	(1.52)	(0.10)	(0.29)
Education	0.0422*	-0.0357*	0.0441**	0.02024	0.0115
	(2.49)	(2.10)	(2.71)	(1.21)‡	(0.68)‡
Unemployed	0.00599	0.0319	-0.0518	0.0366	0.0108
	(0.15)	(0.79)	(1.35)‡	(0.94)	(0.27)
Manual	0.0105	0.0137	0.00413	-0.0320	0.00628
	(0.39)	(0.51)	(0.16)	(1.20)‡‡	(0.23)
Married	-0.0307	-0.00588	-0.0178	0.0156	-0.0178
	(1.20)	(0.23)	(0.72)	(0.62)	(0.69)
Widow	-0.0791	0.0699	-0.0849	-0.0114	-0.0832
	(1.74)	(1.52)	(1.92)	(0.25)	(1.81)‡‡
Children	-0.0304	0.0334	-0.0301	-0.0804**	-0.00674
	(1.28)	(1.39)	(1.31)	(3.42)	(0.28)
Muslim	0.0570	0.1246	0.0350	0.1471*	0.0676
	(0.85)‡‡	(1.89)‡	(0.55)‡	(2.24)‡‡	(1.02)‡‡
Catholic	-0.0394	0.0444	0.00019	-0.0325	0.0699*
	(1.36)	(1.51)	(0.01)‡	(1.14)	(2.40)
Orthodox	-0.1474*	0.1543*	-0.0965	-0.0635	0.1545*
	(-2.25)	(2.38)	(1.55)	(0.99)	(2.41)
Other religion	0.0287	-0.00573	0.00026	-0.00656	-0.0148
	(0.91)	(0.18)	(0.01)	(0.21)	(0.46)
Pay bills	0.0395*	-0.0313	0.0277	0.0282	-0.0457**
	(2.42)	(1.90)	(1.77)	(1.76)	(2.78)
Consumer durables	0.0518**	-0.0475**	0.0539**	0.00203	-0.0332**
	(4.53)	(4.13)	(4.90)	(0.18)‡	(2.86)‡
Farmer	0.1736	-0.1603	0.2445**	0.0745	-0.0232
	(1.89)	(1.75)	(2.79)	(0.83)	(0.25)
Impact on Men of studying science					
Father:	0.166*	-0.1858*	0.1893*	0.2472**	-0.0569
	(2.07)	(2.28)	(2.40)	(3.10)	(0.70)
Mother:	0.136	-0.1411	-0.0601	0.1129	0.1106
	(1.27)	(1.30)	(0.57)	(1.06)	(1.03)
Respondent	0.1648**	-0.2029**	0.233**	0.0989**	-0.1301**
	(4.49)	(5.37)‡	(6.50) ‡	(2.71)	(3.48)
Impact on Women of studying science					
Father:	0.218*	-0.1997*	0.2178*	0.0686	0.0255
	(2.42)	(2.22)	(2.56)	(0.78)	(0.29)
Mother:	0.0862	-0.1341	0.0276	0.2532*	-0.1141
	(0.84)	(1.30)	(0.27)	(2.52)	(1.12)
Respondent	0.1541**	-0.1436**	0.1472**	0.0389	-0.0593
	(4.07)	(3.77) †	(4.04)	(1.04)	(1.56)
3rd Threshold (α_1)	-1.632	-0.4726	-1.143	-0.1286	-0.7697
2nd Threshold (α_2)	-0.6487	0.4307	-0.0685	0.8348	0.2056
1st Threshold (α_3)	0.1377	1.1468	0.6338	1.1569	1.200
Observations	12437	11818	12865	13244	11606
Log Likelihood	-15320	-14881	-16871	-15185	-15050

X^2	726.3	761.5	699.8	699.2	625.8

Note: See Table 4. ‡‡/‡ denotes a significant difference at the 1%/5% levels, in a pooled regression (not shown) in the impact on attitudes to cisgenesis and transgeneis.

Table 6:
Regression Results: Attitudinal Determinants of Approval

	Apple Cisgenesis: Regression Coefficient	**Marginal effects**	**Apple Transgenesis: Regression coefficient**	**Marginal effects**
Risk	-0.1808** (10.21)	-0.03367	-0.6411** (32.89)	-0.0600
Gain	1.0330** (63.03)	0.19226	0.7054** (38.57)	0.0660
Environment harm	-0.1206** (6.51)	-0.02245	-0.1620** (9.99)	-0.0152
Natural	0.3456** (23.03)	0.06434	0.2377** (15.33)	0.0223
1st Threshold (α_1)	1.611		-0.7281	
2nd Threshold (α_2)	2.833		0.6988	
3rd Threshold (α_3)	4.583		2.3326	
Observations	11504		10697	
Log Likelihood	-10001		-8480	
X^2	10916		10311	

Note: See Table 4. Regressions include the country dummy. The marginal effects relate to the impact of changing the right hand side variable, e.g. perceived risk, on the probability of someone 'totally' approving of the technology, i.e responding 'totally agree' to the question on encouragement defined in Table 1.

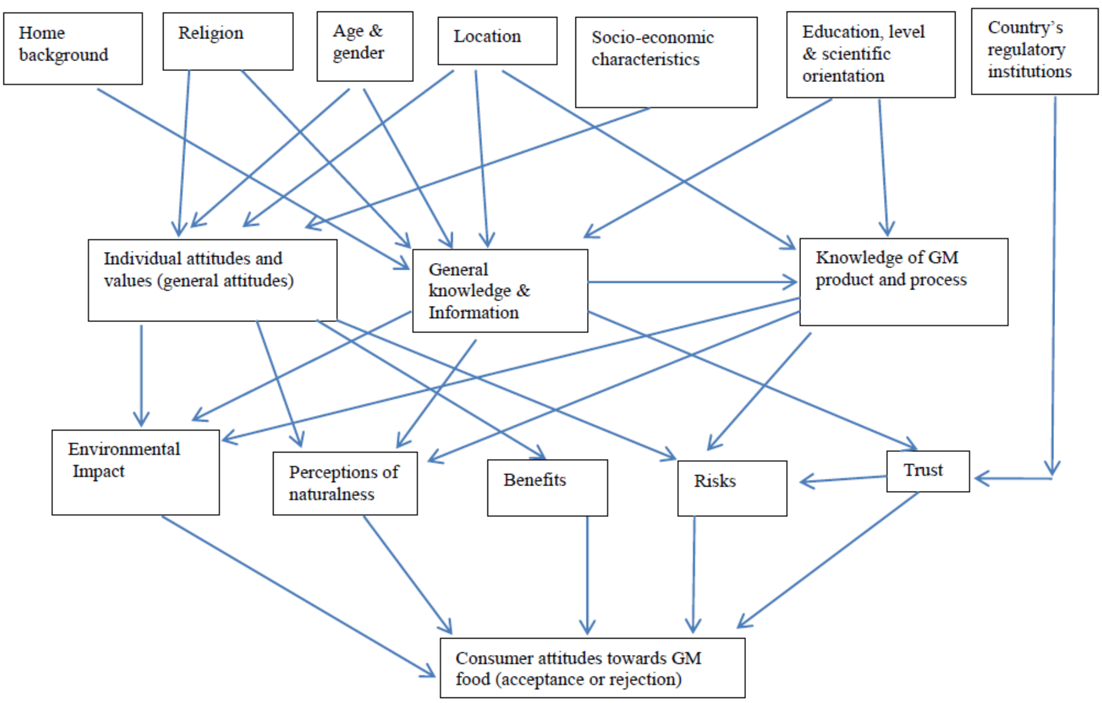

Fig. 1. The determinants of consumers' attitudes to GM food.

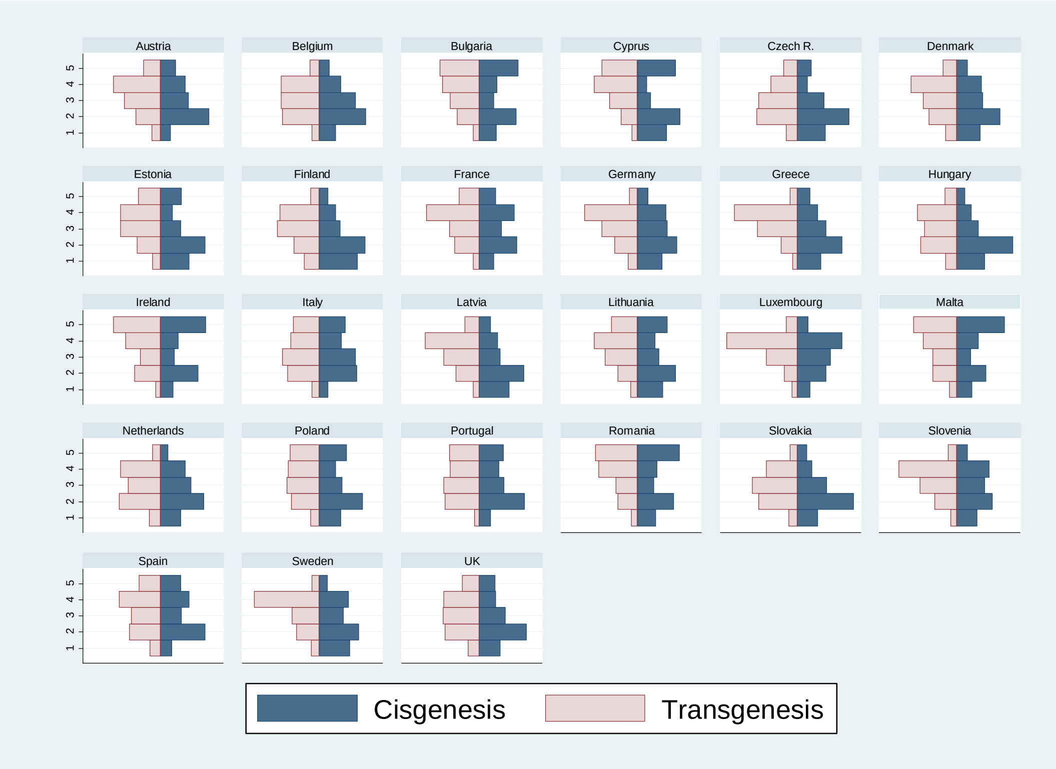

Fig. 2. Approval for Cisgenesis and Transgenesis across the EU, Coded 1(Totally agree that it should be encouraged) to 4 (totally disagree) and 5(Don't know). Each country shows back to back bar graphs as in a population pyramid. Source: Derived from Eurobarometer survey 73.1